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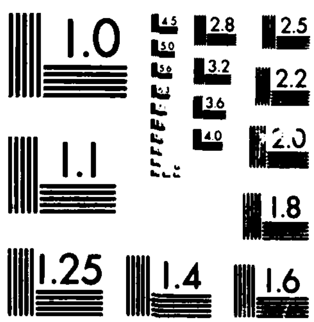


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The Interactions Measurements Payload for Shuttle (IMPS) is being developed by the Air Force Geophysics Laboratory (AFGL) to study interactions between large space vehicles such as the Shuttle and the low-altitude plasma environment over the polar-caps and in the auroral zone. The Jet Propulsion Laboratory has been assisting AFGL in the development of IMPS by preparing a preliminary mission plan. This report details that plan and presents a long-range program for studying spacecraft interactions. The specific technology questions addressed in the IMPS mission are: what are the limits within which high voltage/high

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power systems can be operated without arcing or significant power loss, what hazards might hamper astronaut EVA in the auroral and polar-cap regions, can the deleterious effects of plasma interactions be limited, does passage through the auroral and polar-cap regions affect the shuttle-induced bay environment, and how do material properties change during a shuttle mission and do these changes alter shuttle interactions with the environment. Three versions of the IMPS payload capable of addressing these issues are presented. These payloads include experiments from numerous institutions: AFGL, NASA Lewis, NASA Johnson, NASA Goddard, JPL, and Aerospace Corp. The report concludes with a list of specific recommendations for future IMPS efforts.

FINAL REPORT

for

AIR FORCE GEOPHYSICS LABORATORY

PROJECT ORDER No. ESD 2-0813

# INTERACTIONS MEASUREMENTS PAYLOAD FOR SHUTTLE (IMPS)

## ABSTRACT

The Interactions Measurements Payload for Shuttle (IMPS) is being developed by the Air Force Geophysics Laboratory (AFGL) to study interactions between large space vehicles such as the Shuttle and the low-altitude plasma environment over the polar caps and in the auroral zone. The Jet Propulsion Laboratory has been assisting AFGL in the development of IMPS by preparing a preliminary mission plan. This report details that plan and presents a long range program for studying spacecraft interactions. The specific technology questions addressed in the IMPS mission are: what are the limits within which high voltage/high power systems can be operated without arcing or significant power loss, what hazards might hamper astronaut EVA in the auroral and polar cap regions, can the deleterious effects of plasma interactions be limited, does passage through the auroral and polar cap regions affect the shuttle-induced bay environment, and how do material properties change during a shuttle mission and do these changes alter shuttle interactions with the environment. Three versions of the IMPS payload capable of addressing these issues are presented. These payloads include experiments from numerous institutions:

AFGL, NASA Lewis, NASA Johnson, NASA Goddard, JPL, and Aerospace Corp. The report concludes with a list of specific recommendations for future IMPS efforts.

# I. INTRODUCTION

As spacecraft become larger and more complex, the effects of the space environment on spacecraft systems will likewise grow more severe and complicated. The Interactions Measurements Payload for Shuttle (or IMPS), to be described in this report, is designed to address a specific part of this problem: engineering interactions between a large vehicle such as the Shuttle and the low altitude plasma environment over the polar caps and in the auroral zone (regions of critical concern to the Air Force and its mission in space). IMPS is conceived as a Shuttle experiment designed and developed by the Air Force Geophysics Laboratory (AFGL) to study this problem. During the last year, the California Institute of Technology's Jet Propulsion Laboratory (JPL) has been assisting AFGL in the development of IMPS. The results of JPL's activity during FY 82 are reported here and represent the culmination of the preliminary IMPS planning effort.

The IMPS project will provide information critical to the establishment of a technology base on the effects of the cold ionospheric plasma at Shuttle altitudes on future high voltage/high power AF systems and on the potential concerns associated with passage through the auroral zones. While little difficulty has been experienced by previous vehicles in these environments, it is known from laboratory tests that many new problems are to be expected as vehicles become larger and more complex. Such complexity, while significantly enhancing man's ability to perform useful tasks in space, has often resulted in increasing sensitivity to the space environment. IMPS is intended to prevent such technological surprise

from limiting future missions.

The IMPS payload is being designed to address 5 basic technological issues:

1. What are the limits within which high voltage/high power systems can be operated without arcing or significant power loss?
2. Are there any unforseen hazards such as spacecraft charging which might hamper astronaut EVA in the auroral and polar cap regions?
3. Is it possible to eliminate or at least limit the more deleterious effects of plasma interactions?
4. How does passage through the auroral and polar-cap regions affect the Shuttle-induced bay environment?
5. How do material properties change during a Shuttle mission and do these changes alter Shuttle interactions with its environment?

Several experiments have been tentatively identified which address the 5 questions just posed. AFGL is developing an automatic charge control system that offers the possibility of actively controlling Shuttle potentials. JPL has proposed two experiments: one intended to study the effects of the polar and auroral environments on microcircuit upsets (the polar regions—where the AF is concerned--differ significantly from the equatorial regions--where NASA is concerned--in the level of cosmic ray fluxes, which generate microcircuit upsets) and another to study changes in the electrical properties of materials. NASA Lewis has available its PIX experiment which is a large panel capable of simulating the effects on a high voltage solar array. NASA Johnson has tentatively suggested an

experiment to measure the potential on the astronaut MMU and life support system during auroral passage when potentials might reach thousands of volts under certain conditions. NASA Goddard has suggested flying an electrical interference measurement system while Aerospace intends to measure satellite potentials, arcs, and contamination in the Shuttle bay. AFGL will provide a complete plasma diagnostic package in support of these engineering experiments.

This report will review the preceding in more detail with the intent of developing the outline for a long-term spacecraft interaction study of which IMPS will be a key ingredient. In the first section, the work accomplished in FY 82 will be reviewed with emphasis on several meetings that were held to develop the IMPS concept. The mission concept that developed from these meetings will then be discussed. Following a description of the three DoD Form 1721's (AF Requests for Spaceflight) prepared for IMPS, the overall IMPS briefing package will be briefly reviewed. The final sections will address the specific issues of:

1. Where should the vehicle charge control system be placed?
2. What form should the ground test plan for IMPS take?
3. Where should the IMPS program go in the next 2 decades?

The report concludes with recommendations on how the IMPS program should proceed in FY 83 and beyond.

# II. PROJECT ACCOMPLISHMENTS IN FY 82

## A. INTRODUCTION

As originally outlined in the task plan, JPL was directed to develop for AFGL a conceptual payload design plan and support documentation for IMPS. The work carried out by JPL in accomplishing this task is reviewed in this section. By way of summary, JPL convened an internal payload definition panel to prepare a preliminary design for the IMPS. In conjunction with this panel, a 2-day conference was held at JPL in December of 1981. Approximately 70 experts in a number of the key spacecraft interaction areas attended this conference. Their inputs were used to develop an initial IMPS experiment list which was subsequently reviewed and modified by AFGL. Three payloads were defined for which JPL prepared three DoD Form 1721's. Reviews and meetings between AFGL, JPL, and Air Force Space Division personnel lead to further revisions to the original payload concept. Toward the end of this effort, emphasis also included the manned aspect of the Air Force space program. Meetings were held at Martin Marietta Corporation and at NASA Johnson to develop a clearer picture of the types of environmental effects that would be of concern to the AF man in space program. The results of these planning exercises are described in the following sections.

## B. MEETINGS

Although numerous reviews and day-long interchanges were carried out during the course of the IMPS task, two meetings stand out as being of the most value to the program. The first of these, on 15-16 December 1981, provided a rich resource of ideas and experiments for IMPS. The second set of meetings at Martin Marietta and NASA Johnson, while much smaller, provided critical insight into the NASA manned spaceflight program and potential problem areas that could be addressed by IMPS.

The December IMPS meeting was held at JPL in order to determine interest in the IMPS program and to obtain information on possible experiments appropriate for inclusion on IMPS. A third objective was to obtain a consistent rational for the criteria to be used in selecting the IMPS payload. As a consequence, this first meeting was open to the scientific and engineering community at large. The response to the invitation and the resulting dialog at the meeting revealed a sincere interest by the scientific and engineering community in studying interaction phenomena in the auroral and polar regions.

The first day of the December meeting was devoted to outlining the idea behind the IMPS mission--namely the idea of developing a Shuttle pallet to study relevant interactions in the auroral and polar-cap regions. Space Division and NASA programs in the area of large structures and manned flight were reviewed. Following two reviews on the expected auroral zone and polar-cap environments, specific problem areas were addressed. These

ranged from a discussion of electromagnetic interference in the Shuttle bay to a discussion of chamber tests of spacecraft charging in environments similar to that of the Shuttle. The implications of these studies, subsequently borne out by actual Shuttle flight experiments, are that new and yet-to-be-understood adverse interactions are likely as vehicle size and power increase.

The second day of the IMPS meeting addressed two topics. The morning concentrated on reviewing the Shuttle, its capabilities, and the costs involved in a launch. Experiment questionnaires were distributed (approximately 70 were ultimately returned). Following a discussion of specific areas of engineering concern (i.e., thermal effects, mechanical interactions, electrical concerns, radiation damage, and contamination), the meeting was opened to general discussion of IMPS mission goals.

The matrices in Figures 1 and 2 summarize the principle findings of the December meeting. In both cases the left column represents the 5 major types of classes of interactions defined at the meeting (and later revised in meetings at JPL and AFGL). Briefly, Bio-Medical is taken to represent effects on astronauts such as caused by radiation damage. Large Systems refers to effects unique to the physical size of a structure such as gravity torques. Electrical Systems refers to effects associated with the spacecraft electronic systems such as spacecraft charging and the resulting arc discharge. Optical Systems refers to the effects associated with optical sensors such as degradation and loss of sensitivity due to contamination. Orbit/Pointing Accuracy refers to the effects of drag and

torques on the satellite location and ability to point accurately at a given target. Each figure lists the specific effects expected in each class as functions of either particle energy or wave frequency. Although the final areas addressed by IMPS differ somewhat from the classes presented, these figures proved of great value in subsequently categorizing the 70 experiments suggested to JPL and in defining the 3 IMPS payloads.

The second series of meetings that were of particular value in defining the IMPS payload took place on 21-22 July 1982. The first meeting was at Martin Marietta Corporation in Denver, Colorado, and involved personnel from Martin, AFGL, and JPL. The purpose of the meeting was to obtain information on the Martin-designed Manned Maneuvering Unit (MMU) and the Flight Service Station (FSS). These are, aside from the actual spacesuit, the chief components of the Shuttle Extra-Vehicular Activity (EVA) system. As it was desirable to determine the susceptibility of the (EVA) system to auroral and polar interactions (vis a vis AF man in space activities), this interchange was of value in establishing a data base on the technologies involved in EVA. Aside from the technical data obtained, the main conclusion was that the thermal control paint (Chemglaze A276) is relatively non-conducting and may build up sufficient charge to arc. It was determined, however, that, as presently conceived, the MMU and FSS systems are probably not very sensitive to discharge (see, however, discussion of EVA systems in following).

The single most valuable meeting held in conjunction with the IMPS EVA interaction study was at NASA Johnson on 22 July. This meeting, hosted by Dr. A. Konradi and M. Rodriguez of NASA Johnson, defined the key issues associated with EVA interactions. The basic conclusion of this meeting was that, as now configured, the shuttle EVA system is relatively immune to spacecraft interactions as it is predominately dependent on mechanical control devices. Barring a direct arc through the astronaut and his pure oxygen environment, there appears to be little likelihood of an adverse effect on the astronaut. This does not rule out possible interactions of the astronaut with other systems through contamination (the EVA system dumps about 2 pounds of water per hour of EVA) or contact (the astronaut could arc to a sensitive satellite system while working on a satellite). The key concern to arise from these discussions was, however, that future EVA systems will employ sophisticated electronic control and monitoring components that will likely be sensitive to electrostatic charging and could endanger the astronaut if they fail. The new PLSS Caution and Warning System will, for example, be microprocessor based. Thus the testing of EVA electronic systems is a valid issue for IMPS and will require careful consideration in the final IMPS design.

## C. MISSION DEFINITION

### C.1. Mission Goals

The IMPS meetings went far in helping to define the goals of the mission. Ultimately, however, it was necessary to limit those goals given the realistic constraints imposed by cost and Shuttle capacity. Summarized very succinctly, the goals chosen were:

1. Measure potentials on the Shuttle resulting from orbital/environmental interactions.
2. Simulate high-voltage array interactions.
3. Characterize arc discharges and electrical properties of materials.
4. Quantize the electromagnetic and contaminant environments in the Shuttle bay.
5. Test the efficacy of charge control techniques.
6. Evaluate effects on astronaut support systems.

These goals represent a distinct subset of the family of interactions listed in Figures 1 and 2. Even so, the design of a Shuttle pallet to carry out an adequate study of even this subset is still extremely involved. In this section, following a short discussion of the reasons for developing three rather than one payload, the actual payload will be discussed. Although necessarily brief, this discussion is intended to cover the key features of the IMPS mission and the rationale that went into its definition.

C.2. Why Three Payloads?

In addition to the above goals, a major requirement attached to the JPL IMPS study for AFGL was the necessity for providing 3 versions of the IMPS pallet for flight on the Shuttle. The reason for this requirement on the part of AFGL was the desire to develop an inexpensive pallet payload system that could, with modular packages, be adapted to a variety of situations. A key ingredient in the IMPS program is this adaptability. Ideally, IMPS will be capable of reflight with many different host payloads permitting IMPS to carry out long baseline studies and, at a fraction of the cost necessary to develop a new payload, be readily altered to study any new or critical interactions uncovered by previous missions. Further, with the Shuttle, the IMPS payload can be returned for recalibration in the laboratory so that the flight observations can be more accurately evaluated with post-flight data.

Since a primary objective of the IMPS mission is to establish the technology base necessary to prevent adverse environmentally induced effects on future AF missions, it is desirable that, aside from cost, IMPS be easily integrable into any possible "launch of opportunity". Again the modularization of IMPS makes this possible. In designing the IMPS pallet, this ease of integrability translates into a desire for minimal impact on the host mission.

Besides the desire for low cost, ease of modification, and minimal impact on the host mission, IMPS has also been designed with at least one specific flight opportunity in mind--the NASA Solar Array Flight Experiment (SAFE). The basic SAFE package is designed to evaluate the performance of large, high-voltage solar-array systems in space plasmas as a function of self-generated array voltages, panel area, and time. It will allow the validation of interactions postulated from ground testing (i.e., power loss to the ambient plasma) and will obtain the data necessary for comparison with analytical model predictions. It will also provide verification for design guidelines for low-Earth-orbit, high-voltage space power systems. The basic SAFE array will be 4m wide and extend 32m from the Shuttle bay. It will be gimbled and will hold 8 solar-cell modules which will generate power or can be biased relative to space. Several centers are currently involved in SAFE development: MSFC, LeRC, GSFC, JPL, AFGL, and AF Wright Aeronautical Laboratories. Two SAFE equatorial missions are planned in the mid-1980's. IMPS Payload Modification A was designed with the idea of flying with the SAFE as part of a third mission through the auroral and polar-cap regions (note: IMPS is not in any way limited to flying with SAFE but is capable of flying with almost any mission). This would be a particularly useful mission and should be considered as a future possibility.

C.3. The Experiments

Based on the experiments submitted following the December 1981 meeting and on suggestions from JPL and AFGL personnel, the AFGL project office tentatively selected the experiments listed in Table 1. The letter designations correspond to the 3 payloads. Payload A represents the baseline mission; Payload Modification B incorporates a charge control system and high voltage plasma interaction experiment (active experiments that allow IMPS to simulate and study the interactions associated with large, high-voltage solar arrays); Payload Modification C incorporates an experiment designed to evaluate interactions associated with EVA. Payload Modification B incorporates all of Payload A while Payload Modification C incorporates A and B. The three payloads are illustrated in Figures 3,4, and 5.

The IMPS experiments can be divided into 3 blocks: active experiments, engineering experiments, and environmental sensors. Each of these blocks is described in detail below.

ACTIVE IMPS EXPERIMENTS:

1. CHARGE CONTROL SYSTEM (CCS) - Given the problems known to be associated with spacecraft charging, the development of a charge control system for large structures has become a necessity for future missions. The AFGL Charge Control System is being designed to meet this need and will be tested as part of the IMPS mission. The CCS consists of 3 components:

1) sensors to detect the onset of charging (3 devices have been chosen to date); 2) a discharge plasma source to mitigate differential charging; 3) a control unit to decide when charging is occurring and automatically activate the discharge source.

2. PLASMA INTERACTION EXPERIMENT (PIX) - The PIX experiment consists of a large surface capable of being biased ±1000 V relative to the space vehicle ground. It returns information on the resulting currents as a function of bias voltage. PIX has been successfully flown by NASA Lewis on several missions. It is expected to cause arcing at moderate to high bias voltages, thus allowing an evaluation of the safe range within which high voltage solar arrays can be operated.

ENGINEERING EXPERIMENTS:

1. ELECTROMAGNETIC INTERFERENCE MEASUREMENTS (EMI) - NASA Goddard has proposed to fly several swept-frequency EMI receivers in the Shuttle bay to measure shuttle-induced EMI. As this interference could potentially seriously affect sensitive DoD communication and detection equipment, it is a high priority IMPS experiment.

2. SINGLE EVENT UPSET PACKAGE (SEUP) - Future systems such as the Space Based Radar propose to fly 100,000's of VLSI circuits with little or no shielding in the auroral and polar regions. High energy particles in these regions are known to cause individual upsets in memory elements. JPL has proposed to quantify this effect, study variations in response as a function of VLSI architecture, and validate laboratory tests by monitoring single event upsets on selected IC's.

3. TEMPERATURE-CONTROLLED QUARTZ CRYSTAL MICROBALANCE (TQCM) - Aerospace Corporation flew a similar quartz crystal microbalance on SCATHA. On IMPS it will be used to measure contamination rates in conjuction with the Material Charging and Discharging Pulse Monitor Experiment and with the Electrical Properties Degradation Experiment. Contamination rates, shown previously by Aerospace to be sensitive to spacecraft charging, will be studied in the presence of induced potential variations from the AFGL CCS. An artificial contamination source will also be included in this experiment.

4. ELECTRICAL PROPERTIES DEGRADATION MEASUREMENTS (EPD) - JPL is proposing to fly an experiment to measure the secondary, back-scattered, and photoemitted electrons from typical satellite materials as a function of time and material. The instrument will consist of a rotating sample tray with 12 samples which will individually be exposed to a variable electron source. The emitted particles will be measured as a function of energy by a particle detector. Electron emission properties of materials are poorly known and contribute large errors to spacecraft charging calculations. Such measurements have never been attempted in space in real time, but are common in the laboratory.

5. MATERIAL CHARGING AND PULSE DISCHARGING MONITOR (MCPDM) - Aerospace flew a prototype of this experiment on SCATHA at geosynchronous orbit. The purpose of the instrument is to measure the charging of exposed satelllite surfaces using the Satellite Surface Potential Monitor that was perfected for SCATHA. This instrument measures potential changes on selected materials as a function of time and changing ambient conditions. The experiment will also allow the detection and measurement of voltage

discharge pulses, as was done successfully on SCATHA. Coupled with the Electrical Properties Degradation experiment and the TQCM, this instrument will provide detailed material and electrical properties measurements.

6. EVA SYSTEMS EFFECTS EXPERIMENT (ESEE) - This experiment is not well defined at this point but, following several discussions with NASA Johnson (which will be the lead organization for this experiment), two likely experiments have been defined. In the first, a fully-instrumented dummy space suit and MMU would be deployed on a cable. The suit would be biased relative to the Shuttle and sprayed by a high-energy discharge source to study the suit's charging and arcing characteristics in the auroral zone. In the other experiment, samples of the suit and MMU materials and electronic circuits would be exposed to the environment and a high-energy discharge source to determine sensitivities to interactions in the auroral zone.

ENVIRONMENTAL SENSORS:

1. AFGL ENVIRONMENTAL SENSOR PACKAGE (ESP) - Accurate knowledge of the space environment is critical to a proper evaluation of the engineering experiments. The auroral environment, in particular, varies greatly in short time and spatial intervals. In response to this need, AFGL is developing an integrated plasma diagnostic sensor package to measure the plasmas and fields in the vicinity of the Shuttle during the IMPS mission. The individual sensors, some of which will be on a detachable platform (see Figure 6) for positioning by the remote manipulator arm, are listed below:

A. DC/LOW FREQUENCY ELECTRIC FIELD EXPERIMENT - This instrument will measure the electric field from 0 to 20 kHz. It consists of three mutually orthogonal dipole antennas which will be extended from the movable pallet when it is outside the Shuttle bay.

B. FLUXGATE MAGNETOMETER - This instrument measures DC and low-frequency magnetic fields using a tri-axial fluxgate magnetometer mounted on the platform.

C. SEARCH COIL MAGNETOMETER - As a complement to the Fluxgate Magnetometer, the Search Coil Magnetometer measures AC magnetic fields using a tri-axial loop antenna. It also is mounted on the platform for ease of positioning and to remove it from the stray magnetic fields in the Shuttle bay.

D. SOFT PARTICLE SPECTROMETER (SSJ) - The SSJ analyzes ions and electrons between 40 eV and 20 keV using 3 curved-plate electrostatic analyzers which measure the differential fluxes at 20 logarithmic steps.

E. THERMAL PLASMA EXPERIMENT - The Thermal Plasma Experiment consists of a spherical Langmuir Probe and a planar ion RPA. These instruments return the density, temperature, and average ion mass of the thermal plasma and density fluctuations from 0 to 2 kHz.

2. AURORAL IMAGER (AXI) - In conjunction with the AFGL ESP, Aerospace Corp. proposes to fly a pinhole camera which measures Bremsstrahlung X-rays. The object is to monitor discrete aurora during both daylight and night-time auroral zone passage. This will allow predictions of intense activity prior to a Shuttle auroral encounter, thus permitting pre-programming of the experiments if necessary.

## C.4. Mission Considerations

Although the instrument complement just described may not be the final set actually flown, the instruments are representative of the ultimate IMPS payload. As a result, they can be used to estimate the size, weight, power requirements, data rates, orbital constraints, mission time lines, and other miscellaneous requirements for the Shuttle. In this section these factors will be briefly described along with various practical mission considerations that have not been previously mentioned. These factors have been used to independently estimate the cost of IMPS, but, due to the preliminary nature of the results, will not be included in this report (detailed results were forwarded to AFGL previously).

The principle considerations in defining the IMPS mission profile were that the orbits cross the polar and auroral latitudes (this necessitates a launch from Vandenberg AFB, CA) when the northern hemisphere is in shadow (this is so that the extensive auroral research facilities avaiable in the northern hemisphere can be employed to their fullest extent), resulting in a winter launch. Therefore, an acceptable orbit would result from a launch in December at an inclination of $90^{o}\pm16^{o}$. A sample orbital ground track for a launch from Vandenberg AFB at 1327 GMT on December 21, 1987, at an inclination of $79^{o}$, and at an altitude of 370 km is illustrated for a few orbits in Figure 7.

A typical timeline for IMPS is presented in Table 2 for a single orbit. A representative table of propellant requirements for such an orbit is presented in Table 3. Required accuracies for the IMPS mission are presented in Table 4 and data requirements in Table 5 along with Shuttle capabilities--note that the Shuttle should be able to meet most of the experimenters' requirements without difficulty. However, IMPS, as currently planned, will fly as a secondary payload on a yet to be determined host mission. Since the Shuttle has available only 8 kbps of real time and 32 kbps of recording capability, if the host payload requires any of the Shuttle capability it will be necessary for IMPS to have its own recorder or real time data link through the TDRSS (Tracking and Data Relay Satellite System) communication system. The IMPS power requirements are listed in Table 5. On orbit, 700 W of power is available (1000 W on ascent) from Shuttle so that again, dependent on the host payload, an auxiliary power source may be required.

The IMPS instruments, including the deployable AFGL ESP instruments, will all be mounted on the so-called Mission Peculiar Equipment Structure (MPES). This mounting structure has already been developed for such uses and is currently available. Its dimensions are given in Figure 8. Table 7 lists the masses, including this assembly, for the IMPS payload.

Aside from these physical considerations, there are other potentially troublesome concerns. Specifically, the AFGL ESP platform may require manual positioning every orbit. Likewise, the crew may also be required to place the Shuttle in certain reference positions (i.e., pointing the bay to

the sun, into the wake, into the ram, etc.). Again, the capability of the crew to do these maneuvers will depend critically on the host payload. Other constraints will be the ESP interface (the Remote Manipulator System internal wiring may be used for this purpose), the ESEE deployment, use of an active contamination source by the TQCM, temperature control of the TQCM, placement of the EMI probes relative to the host payload, and CCS interactions with other instruments. While of concern, none of these issues will likely have a significant impact on the IMPS mission as currently conceived. It is important, however, to keep them in mind as the program develops so that none do become a serious concern at a later time.

## D. DoD Form 1721s

Based on the preceding discussion of goals and description of the proposed IMPS payloads, 3 DoD form 1721s were prepared in accordance with the task requirements. These contain, in abbreviated form, a careful justification (see introduction to this report) of the IMPS mission and details of the payload and mission consistent with those presented here. In addition, a lengthy package of viewgraphs has been prepared and forwarded to AFGL along with the 1721s. These two items represent, aside from this report, the principle technical output of this task during FY 82. Future plans and recommendations are considered in subsequent sections.

## III. ACTIVE CHARGE CONTROL SYSTEM PLACEMENT

A specific task requirement is the placement of the AFGL Charge Control System in the Shuttle bay. Unfortunately, discussions with the AFGL personnel responsible for the CCS indicate that the CCS is not well defined at this point so that a detailed recommendation is not possible or appropriate. Several assumptions about the nature and system requirements for the CCS can be inferred, however, that limit the placement possibilities:

1. As described earlier, it is clear that the CCS will consist of a charging sensor system, a plasma release mechanism, and a controller.
2. Given the desire to make the IMPS a readily integrable pallet, it is likely that as much of the system as possible should be attached to the MPES.
3. The purpose of the CCS is to discharge differential potentials on the Shuttle. As a result, the plasma/beam device that will be incorporated into the CCS will need to produce a low-energy, neutral plasma (ion energy 30 eV) and not a beam of high energy (few keV) charged particles (electrons or ions).

Given these assumptions, it is possible to develop some general guidelines for the placement of the CCS. The first is that, when deployed, the plasma source should have a clear, unobstructed view of the space environment (this does, in fact, appear to be the only major placement requirement at this time) and should be in the vicinity of the surface to

be discharged (as should the charging sensors). Orientation relative to the magnetic field and the Shuttle surface to be discharged is undoubtedly a consideration but the effects are not sufficiently well understood at this point to affect the CCS placement. Beam plasma discharge effects, because of the low energy of the plasma and its neutrality, should be small, however, in comparison to high energy beams. By the nature of a low energy beam, it should not be well collimated, further reducing the need for a specific magnetic field orientation. Nevertheless, ejection should probably be along the ambient magnetic field lines (this would be a very weak requirement, however).

Perhaps the major interaction problem to be considered in the placement of the CCS is its effect on other instruments. Specifically, the contamination of sensitive surfaces by any backflow of charged particles from the release device must be considered in its placement. As a rule, the plasma device should be placed well away from sensitive optical or other surfaces. The possible interference of the backflow of particles on measurements of the ambient low energy plasma also requires careful consideration. Other possible interactions include light and electromagnetic noise from the plasma source.

Based on these general considerations, the best solution to the CCS is to place the control system on the MPES as indicated in Figures 3 and 4. The charging sensors should go on those areas where charging is to be controlled. The plasma source itself should be placed near the areas to be discharged but far enough away from the main IMPS payload and platform that

the backflow does not cause interference. This includes both physical contamination and electromagnetic noise. It may be desirable, however, to be able to map out the plasma cloud created by the plasma source and to use it as an artificial arcing source. The plasma and field detectors on the platform are capable of maneuvering close to the source for this purpose and the EMI sensors should likewise be strategically placed to detect any arcing in the vicinity of the plasma source. Beyond these general considerations, however, it is not possible to provide more details until the host payload and the CCS are better defined.

## IV. GROUND TEST PLAN

### A. INTRODUCTION

A major consideration missing from the preceding IMPS project description is that of a ground test program. Aside from the obvious need for calibration and payload integration testing prior to launch, IMPS can be tested post-flight because of the inherent "returnable" nature of Shuttle missions. The intent of this section is to describe in general terms a possible ground test program that would enhance the usefulness and increase the understanding of the IMPS data.

## B. PRE-FLIGHT TESTING

Aside from the testing necessary to demonstrate that the flight instrumentation will perform on orbit, many of the instruments are capable of carrying out useful laboratory tests prior to flight. Many of these experiments would be of value in studying spacecraft interactions in general. Several simple examples will be presented below.

As a first example, the Goddard EMI instrument will work on the ground. A prototype was apparently used to obtain preliminary estimates of the EMI in the Shuttle bay prior to the first Shuttle launch. Such measurements are of great value in developing protection for EMI-sensitive Shuttle payloads (the EMI experiment might also be employed to monitor the effects of nearby lightning strikes on payloads inside the Shuttle bay prior to launch). For IMPS, the EMI package could be used prior to launch in conjunction with plasma simulation studies (see below) to characterize arcs and plasma noise. This could greatly simplify the classification of arcs during the actual mission. The Aerospace MCDPM could also be utilized in this capacity and, if the systems could be placed in their flight configurations, a technique for arc location could be developed that would also enhance mission capabilities.

As a second example, the EPD and the surface charging portion of the MCDPM could be employed to develop catalogs of spacecraft charging properties prior to the actual flight of IMPS. Not only would this assist in the calibration of these instruments, but the information they would

provide is in and of itself important in a number of space applications. To date efforts at characterizing spacecraft charging properties have been minimal. The experiments could also be similarly employed to determine the properties of specific Shuttle surfaces prior to their being subjected to launch, flight, or rentry environments. As will be discussed below, such studies could be coordinated with similar post-flight studies.

Ground testing of the AFGL CCS is already an integral part of that development program. Previous charging sources developed by AFGL have been utilized in NASA tests of solar panel charging. Similar sources are used currently to study the so-called beam plasma discharge phenomenon in vaccuum chambers. The characteristics of the CCS (namely low energy and a neutral plasma) should make it particularly useful in tests with the Lewis PIX (PIX-like solar array tests have been carried out at Johnson and Lewis). Much still remains to be learned from such chamber tests, and the existence of PIX and CCS prior to the IMPS flight would allow the study of a number of interesting plasma interaction phenomena.

Although the Johnson ESEE is not yet well defined, several interesting experiments could be performed even at this date. For one, the MMU and suit materials need to be characterized electrically and the IC's being considered for incorporation in future versions evaluated for electrostatic sensitivity. This information, aside from assisting in the development of the ESEE, would aid in the design of new, safer EVA systems. Likewise, the potential danger that the astronaut might pose to a satellite subsystem that he might come in contact with due to his own static charge could be

investigated on the ground in vaccuum chambers prior to launch.

## C. POST-FLIGHT GROUND TESTING

In addition to the pre-flight tests described above, there are unique post-flight ground test opportunities afforded by the IMPS mission. Principal among these are the opportunities to recalibrate the instruments and test assumptions about how an event occurred by conducting chamber simulations with the actual flight hardware. In particular, if an arc was postulated to have occurred at a specific point and to have, as a result, certain electrical characteristics, it should be feasible to test such assumptions by setting up the configuration, synthesizing the arc source, and comparing the results with the original observations. Ideally, such an experiment should permit an unambiguous test of the original assumptions.

Material samples can be retested to determine the effects of the space environment on their properties. Depending on the handling of the materials, the effects of rentry could also be studied systematically. Testing of small portions of the Shuttle itself prior to launch and after return would undoubtably be of additional value. As already noted, several of the IMPS instruments are capable of accomplishing this. Additional testing using standard laboratory equipment could be carried out. This latter type of testing would be valuable in determining the sensitivities of the IMPS instruments.

A final type of post-flight testing that would be of value is that involved in reconfiguring the system. The initial flight in any series always indicates ways to improve the basic design. With IMPS, as it is intended to be reflown, the recovery of the payload will permit rapid redesign. Testing of the new payload will benefit from not only the flight data but preceding ground testing. Given better knowledge of the effects considered critical, the reconfiguration testing can concentrate on those areas.

In Table 8, a possible ground test schedule is presented that incorporates the ideas presented in the preceding paragraphs. The table is centered on the launch date and indicates pre-launch and post-launch activities. Pre-launch experiment calibration and systems integration testing have been left out of the table as these would be included in the detailed IMPS program plan that is the follow on to this effort.

## V. IMPS ADVANCED CONCEPTS PLAN

### A. Introduction

IMPS does not exist in a vacuum. Several other missions (see Table 9) directly related to the IMPS program goals are currently planned for the same time frame. Likewise, the IMPS advanced program concept is not limited to a single flight. In fact, in order to obtain the maximum value from IMPS, it is necessary to integrate the program into other planned efforts and to incorporate the IMPS program into a long range plan. In

this section, such a long range plan will be developed with emphasis on future IMPS payloads and missions into different space environments. Athough not intended as a detailed plan, the phased approach presented should provide the skeleton for such a program.

In planning a long range space program of the scope of IMPS and its companion flights, a phased approach is a necessity. Here the long range plan has been divided in to 5 phases. Briefly, the first phase will be an information phase, the second a simulation phase, the third an integration phase, the fourth the actual flight phase, and the final the analysis phase. Each phase can exist concurrently with the others (i.e., information will undoubtably be gathered throughout the program) and the process will be repeated for each flight.

B. Phase 1

The purpose of the first phase is to gather data. There are numerous methods of accomplishing this and indeed the current task has had this as the primary objective. The four principal means employed by the current task are illustrative of the types of activity to be carried out in this phase:

1.) Collect documentation
2.) Conduct workshops/conferences
3.) Visit key facilities
4.) Utilize a panel of experts

As an illustration of the first method, numerous literature searches were carried out for AFGL on specific IMPS concerns. For example, a bibliography of papers on Skylab EVA's and man-in-space hazards was generated for AFGL use. Several reviews of spacecraft charging and plasma interactions were prepared. In reference to method two, the workshop in December 1981 has been discussed. Key facilities such as Martin Marietta and NASA Johnson were visited and data on IMPS issues collected. Likewise, an internal JPL panel was convened to prepare the preliminary IMPS plan. Thus Phase 1 has begun for IMPS 1.

Building on the IMPS data base, future flights should concentrate on specific interaction concerns. In September 1982, AFGL held a workshop on the charging of large space structures in low altitude orbits. Such workshops should be continued and should form an integral part of the IMPS long range program. As illustrated in Table 9, small workshops on key interaction issues should be scheduled at least once a year. These should be held at different organizations which have an interest in spacecraft interactions so as to get the widest possible publicity for the issues involved.

In concert with the topical meetings, at least every 2 years a general conference should be held (such a conference is planned for fall 1983). Based on the workshops and these conferences, a permanent data base of references on spacecraft interactions can be developed. The material in this data base should be divided by interaction effects and cross-referenced to the specific systems affected.

Blue-ribbon panels should be organized on a permanent basis to advise the existing AF/NASA Technology Panel on progress in mitigating the individual problems and as to future research (some specific panels are listed in Table 10). A master-technology road map in the area of spacecraft interactions should be developed (the rudiments of such a plan actually exists within the joint AF/NASA technology program) based on the findings of these panels.

## C. Phase 2

In the second phase, the main thrust is to improve the capability to simulate interactions. Given the existence of the data base on spacecraft interactions developed in phase 1, the adequacy of the existing models and experimental data associated with the different interactions can be evaluated. This information can be used to determine where our simulation capablities need to be improved and where more data are required. Again, several approaches are necessary and, as indicated in Table 9, this too is a continuing process. Two approaches are considered here:

1.) Theoretical modeling
2.) Ground simulation.

As in any scientific activity, our ability to control a given phenomenon is dependent on the adequacy of the theoretical models used to define it. In studies of spacecraft interactions, an adequate understanding of the phenomenon includes an understanding of the source

(the environment), of the victim (the space system), and of the interaction (spacecraft charging, radiation damage, etc.). The model then attempts to simulate the effects of the source on the system. Currently, although fairly adequate models of the space environment exist and systems can be modeled to some degree, interaction models are at a very rudimentary level in general (dosage and shielding calculations are an exception). Thus the development of adequate models is a primary concern.

An invaluable adjunct to such models is actual experimentation. Even with the advent of Shuttle, ground testing remains in most cases the cheapest and easiest way to study many phenomena associated with spacecraft interactions. It is suggested in this plan that such ground simulation be given at least as high a priority as the modeling efforts. The primary problem to date with ground testing has been problems with scaling of plasma phenomena and with simulation of the space plasma characteristics. In a departure from previous studies, it is recommended here that specific facilities be developed and dedicated to simulating each of the principal space plasma environments (namely, the plasma associated with low earth orbit, polar earth orbit, the aurora, and geoysynchronous orbit and the energetic particles associated with the radiation environment). Likewise, adequate simulations of particular phenomena are also necessary (launch conditions, rocket plume effects, arcing, high voltage surfaces, etc.).

In Table 11, according to the type of interaction (here the interactions are defined as those associated with radiation effects, spacecraft charging, large high-voltage structures, contamination, and

effects of space systems on the environment), are tabulated several classes of experiments that would support the IMPS program. In the third column are listed different types of ground simulations necessary to analyze the interactions. In the final column, as described earlier, are listed the types of analytic models that are required to describe the interactions. This table, like Figures 1 and 2, is particularly useful in providing a framework for conceptualizing the overall needs of an interaction technology base.

D. Phase 3

In the first two phases, the tools necessary to determine the gaps and weaknesses in the interaction technology base were established. In Phase 3, the steps necessary to develop and integrate the IMPS or its associated missions will be carried out. The first phase will have helped finalize the given mission so that the instrumentation will be optimizied for studying the relevant interactions. The second phase will have provided the tools for testing the payload and for determining the range and nature of the interactions to be observed. In the case of IMPS, chamber tests will allow the validity of the experiment designs to be tested under realistic conditions typical of the low earth and polar orbits and, by varying the environments, allow extrapolation to other regimes such as geosynchronous. The analytic models, if available, will similarly allow extrapolations to other space environments. As currently envisioned, the integration phase of the IMPS program would make use of all these factors to develop coordinated experiments and timeliness for the IMPS flights so

that the maximum amount of data will be obtained by each one. This phase has been included as an integral part of the plan, as indicated in Table 9.

E. Phase 4

Although the most exciting and stressing part, there is little to be said about the flight phase of IMPS and its sister missions. Instead, in Table 9 are listed 4 possible follow-on flights for IMPS. The intent is to slightly modify the IMPS payload so that the interactions typical of each of the key space regimes defined above are emphazized. Those missions, in chronological order, are:

1.) IMPS 1--Polar earth orbit/auroral zone. This is the principle IMPS mission now envisioned and outlined in this report.

2.) IMPS 2--Low latitude plasmasphere/ionosphere-large structure. Although the primary IMPS mission will pass through this regime, the mission is not optimized for this region nor will it necessarily fly with a large structure (1 km or larger). Such large structures as the prototype of the space based radar or an AF/NASA space station should be available by the time of this launch. Depending on the size and complexity of the structure, multiple ESP packages could be deployed to simultaneously monitor the environment around the structure.

3.) IMPS 3--Polar cusps/magnetosheath. Although currently not really accessable to the Shuttle, improvements in the Shuttle or a free flyer should make a flight into this region possible in the indicated time frame. The IMPS package should be modified to allow better detection of ambient

electric fields and time variations in the ambient electric fields and plasmas in this region, as the primary environmental issues are rapid fluctuations in these parameters.

4.) IMPS 4—Geosynchronous. Although SCATHA flew in this region, by the time indicated on the chart the need for further studies of this region should have developed. Given the experience gained over the preceding IMPS missions, such a flight should yield valuable new results in time for the design of a geosynchronous space station. The CCS will likely need to be modified to control the rapidly varying, high-energy fluxes associated with the geosynchronous environment. Likewise, the ESP should be modified to better measure these plasma variations. Long term exposure of materials to the geosynchronous environment should be considered as a valuable issue on this mission. Such long term exposure implies modifying IMPS so that it can be used as a free flyer.

5.) IMPS/SAFE--Polar earth orbit/auroral zone. As discussed earlier, a joint mission with the NASA SAFE array would be of mutual benefit to both programs. It would afford IMPS the possibility of flying with a large, high-voltage structure. For SAFE, the IMPS diagnostic capabilities would be of great value in studying interactions with the auroral and polar regions. As IMPS has been designed with such a mission in mind, no modification to the basic IMPS 1 package is necessary.

F. Phase 5

The most critical phase for IMPS will be the analysis phase. Although (as already indicated) invaluable data can be gained from ground testing, analysis of actual flight data is the ultimate step in gaining a real understanding of interactions. Further, for the IMPS program to be of any lasting value, that understanding has to be documented. As turn-around is a crucial issue in adequately disseminating the IMPS data, a carefully conceived data analysis plan incorporating real-time analysis, data workshops, and quantifiable outputs is a necessity. Each of these issues will be addressed for the IMPS and its companion missions in this section.

Real-time analysis of the IMPS data will be a necessity for some of the instruments. In particular, much of the CCS data will be returned in real-time. Its operation, although automatic, will require careful monitoring when the plasma source is turned on. Further, AXI will need to be monitored in real-time to predict the encounter of IMPS with an auroral arc. It is hoped in fact to have specific modes in which the IMPS package can be configured so as to optimize data collection when passing through auroral features. With s ficient forethought the data from such runs would be available for real-time analysis. It is recommended that at least one such optimized real-time run take place each day. Several candidates for such runs would be:

1. Auroral arc encounter. All instruments capable of recording rapid variations should be in their highest time resolution modes and, where

possible, the data should be broadcast back to earth in real-time.

2. Beam operations. Specific experiments employing the CCS should be developed. As was learned from SCATHA, beam operations can induce rapid plasma variations. Although it is assumed that the low energy of the CCS plasma will not cause too much concern, operations of the CCS source should be of special interest.

3. EMI events. If the EMI detectors report peculiar activity, such intervals would be logical candidates for quick analysis.

4. Thruster firings. Past Shuttle flights have indicated that thruster firings can cause significant changes in the Shuttle environment over short periods.

5. Major changes in Shuttle orientation. Changes in Shuttle attitude relative to its velocity vector, the sun, and the earth's magnetic field can all generate interesting variations during the changes.

6. Movement of the ESP. Real-time data analysis of the ESP during its movement would help to indicate locations of interest for further study during the flight.

Such real-time analysis will require the principal investigators to commit to a rigorous schedule during flight. Even so, as evidenced by previous Skylab and Shuttle flights, the ability, based on real-time data, to reconfigure the experiments in real-time is crucial. It should be standard for the IMPS missions to have the experimenters remain after the actual flight to prepare preliminary data bases for their fellow experimenters of these real-time data. An integral part of the program should be a data management system capable of handling such real-time needs.

Within the first year following (and, indeed, in the months preceding) launch, there should be a series of data workshops on the lines of the NASA Goddard CDAW's (Coordinated Data Analysis Workshops). At these workshops, the IMPS data would be available through the data management system so that the experimenters can rapidly intercompare their results. This approach argues for a large central processing unit such as a dedicated VAX and a number of interconnected terminals. By the IMPS launch time (1987-88), such systems should be common. By the time of the later launches, such facilities and procedures will be standard. The key to the workshops, however, is the selection of key topics such as "contamination", "arcing", "charge control", etc. By limiting each workshop to a key topic, it should be possible to generate a report concentrating on that topic as the output of the workshop. These reports should be directed toward improving the relevant MIL-STDs and Guidelines.

A major conference such as discussed previously should be timed to occur within a year to two years of each IMPS mission. These conferences should represent the culmination of each mission and have several sessions devoted to summarizing the results. In particular, the parallel results from the ground test programs should be incorporated into the mission reports at this time. The output from these conferences should be comprehensive mission analysis reports.

Based on the conference reports and the workshop results, the updating of the MIL-STDs and Guidelines should begin in earnest. A time table, spanning the two decades of the IMPS missions should be established for

updating these documents. A tentative time table is presented in Table 9. These updates represent the primary goal of the IMPS program and should be given the highest priority of any items considered thus far!

## G. SUMMARY

The 5 phases necessary for taking the IMPS and its sister missions from concept to utilization have been documented in this section. The major value of this presentation is that it organizes the IMPS mission into a logical sequence of events. It should be remembered, however, as indicated in Table 9, that the phases overlap and repeat. Even so, the progression is clear and will be valuable for future planning efforts.

# VI. CONCLUSION

## A. Summary

This report has detailed the accomplishments of the JPL IMPS effort on the behalf of AFGL during FY82. The primary accomplishments during the year were:

1.) JPL organized and ran a 2-day workshop on IMPS and the scientific and engineering issues associated with spacecraft interactions in the polar and auroral regions.

2.) Three preliminary IMPS payloads and missions were prepared.

3.) Three DoD Form 1721s (Request for Spaceflight) were prepared.

4.) An extensive presentation package was developed for use by AFGL in briefing the IMPS program.

5.) Numerous meetings with industry, NASA Headquarters, and other laboratories were held to publicize IMPS, develop an interest in the mission, and obtain information specific to the flight.

The current report also presents the results of recent advanced planning efforts carried out at JPL on the behalf of the IMPS project. Specifically, concepts and plans concerning the following subjects were discussed:

1.) Plans for the placement of the AFGL Charge Control System.

2.) A description of an extensive pre- and post-flight ground test program incorporating the IMPS experiments.

3.) A 20-year mission scenario with descriptions of 5 possible missions to different plasma regions in the earth's vicinity.

These results represent an important step in beginning the development of a long-range study of spacecraft interactions for DoD. Even with this beginning, however, without adequate follow-on work, the study of spacecraft interactions will continue to progress at the slow pace characteristic of the past two decades. Several recommendations are included in the next section that, if followed, should materially aid the development of interactions technology and hopefully avoid the problems encountered in this area up to now.

B. Recommendations for the Future

If implemented as presented, the IMPS program should be the keystone of the new interaction technology being developed at AFGL, JPL, and elsewhere. There are, unfortunately, likely to be many obstacles to that implementation. Proper action at this time will significantly improve the future chances of the program, however. Specific recommendations for the coming year are:

1.) Develop a sound, easily defensible program plan for IMPS. This document provides the rudiments of such a plan, but clearly lacks the detailed costing and time phasing information necessary for an actual program.

2.) Revitalize the joint AF/NASA technology panel responsible for spacecraft interactions. Supplement this panel with blue ribbon panels in the areas of plasma interactions, astronaut safety, and contamination. It is critical that engineers actually concerned with these problems also be closely involved. Industrial representatives should also be included at the working group level.

3.) Heavily publicize the upcoming spacecraft interaction technology meeting. The meeting should have a definite theme and, aside from the proceedings, should have a definite product goal in mind. That is, in lieu of continuous technical sessions, working groups should be incorporated into the meeting with the idea of producing position papers on such topics as engineering needs, data base requirements, possible mission scenarios, etc. The evaluation of this or a similar plan for a long range interaction

technology plan would also be an excellent candidate topic.

4.) Concentrate short term efforts where possible on implementing the ground test program outlined here. Hard evidence on the seriousness of many of the interactions is still missing and such a ground test program would go far in substantiating their importance.

5.) Develop a permanent data base on spacecraft interactions. This data base would be computer based and accessible by anyone over the telephone. It would include: information on material properties and suggestions as to what to and not to use in specific applications; what environments are of concern for a given orbit and what models are available; lists of relevant papers, MIL-STDs, and guideline documents; an anomaly data base; names of key individuals and institutions; current funding projections and principal funding sources; lists of potential flight opportunities; possible ground test facilities; instruments available for Shuttle reflight or for use in chamber testing; sources of flight or chamber data; etc.

The preceding recommendations could all be rapidly implemented without great cost. Their accomplishment would give the interactions technology program the impetus it needs to begin. Currently, work done in the area tends to be done on a single-program, crisis basis with much duplication of effort. Any of the above steps would begin the process of coordinating those efforts and thereby save millions of dollars of duplication each year. That alone should argue for their immediate implementation.

ACKNOWLEDGEMENTS

Innumerable individuals made direct contributions to this report. Unfortunately only a few of the more significant contributions can be mentioned here. From JPL, C. Wertz contributed the extensive mission plan which makes up most of the report. M. Brownell, with the assistance of D. Vane, contributed the detailed instrument descripitions and carried out the preparation and evaluation of the experiment fact sheets. Dr.S. Gabriel was responsible for the beam plasma placement study. Drs. B. Tsurutani (JPL) and J.M. Forbes (Boston College) provided technical assistance and advice at several key junctures in the study. Dr. Forbes in particular contributed several detailed planning assesments which were the foundation of much of this report (these documents were forwarded to AFGL under separate cover). Dr. P. Robinson, T. Jordan, F. Schutz, and T. Gindorf spent many hours reviewing and critiquing the report. S. Proia provided exceptional administrative support for the study. Finally, the AFGL management team, consisting of Dr. D. Guidice, W. Hall, and C. Pike, were responsible for many of the ideas and comments ultimately incorporated in this final report.

FIGURE CAPTIONS

1. Principal spacecraft interactions broken out in terms of the particles causing the given effect and by the major category of interaction (note: the terms "low" and "high" refer to energy range).

2. Principal spacecraft interactions broken out by frequency and wavelength of electromagnetic wave and by the major category of interaction.

3. The baseline IMPS payload showing the placement of the various subsystems on the MPES. The AFGL ESP is located on a removable platform indicated by the lack of shading.

4. The IMPS payload, modification B. This payload is the same as payload A with the addition of the experiments indicated by a lack of shading.

5. The IMPS payload, modification C. This payload is the same as payload B with the addition of the experiments indicated by a lack of shading.

6. Closeup view of the AFGL Evironmental Sensor Package showing the placement of the various experiment packages and the approximate location of the sensor booms.

7. IMPS ground track for orbits 31 to 46 following a launch from Vandenberg AFB at 1327 GMT on December 21, 1987. For reference the ground track slowly precesses to the west (the cross-hatching on the orbital track lines refers to daylight portions of the orbit). Also indicated for reference are the approximate positions of the northern and southern auroral zones.

8. The IMPS Mission Peculiar Equipment Structure. Dimensions are in inches. The payload center of gravity envelope for maximum load capacity is also indicated.

TABLE CAPTIONS

1. Preliminary list of instruments on the IMPS payload. "A" refers to the baseline payload. "B" refers to the modification B payload which is payload A plus the indicated experiments. "C" refers to the modification C payload which is payload B plus the indicated experiments.

2. Representative mission timeline for one IMPS orbit. Instrument command modes and data rates are indicated.

3. Propellant usage estimates for typical Shuttle maneuvers(note: the Shuttle values represent the amount of fuel needed to start the motion; an equal amount would be needed to stop the motion). A typical example of the fuel requirements for the MCDPM experiment is included.

4. Required accuracies for the IMPS payload compared with the Shuttle accuracy capabilities.

5. Tabulation of data handling requirements for the IMPS payload (Modification C).

6. IMPS power requirements listed by subsystem.

7. IMPS mass requirements by subsystem and by subsystem element for IMPS payload modification C.

8. Preliminary IMPS ground test support plan for FY83-FY90.

9. Master timeline for IMPS program between 1980 and 2000. The timeline indicates the 5 phases (see text) and possible companion missions to the IMPS missions.

10. IMPS support panels listed by key topics.

11. Listing of possible future experiments in support of the IMPS program plan. Also listed are the associated ground simulation and analytic modeling concerns for each class of experiments.

PARTICLES

| EFFECTS ON \ EFFECTS | ELECTRONS LOW* (ENERGY) | ELECTRONS HIGH[1] | IONS LOW* (ENERGY) | IONS HIGH* | NEUTRALS* | PARTICULATE* | MICROMETEORITES/ DEBRIS |
|---|---|---|---|---|---|---|---|
| Bio-Medical | Charging[2] | DNA Damage, Scintillation, Dosage | Charging[2] | DNA Damage, Scintillation, Dosage | Toxic Outgassing | Toxic Particulates | Spacesuit Damage |
| Large Structure | Charging[4] | | Charging | Sputtering, erosion, implantation embrittlement | $\alpha$, $\epsilon^3$ change from contamination | $\alpha$, E change from surface damage | Physical destruction |
| Electrical Systems | Surface Charging, HV power loss, multi-pacting plasma wake | Charge Deposition, Dosage | Charging, Plasma Wake | Single Upsets, Dose, Dose Rate, | ——— Solar Cell Damage Through Surface changes ——— | | |
| Optical Systems | ——— Damage to Coatings ——— Charging[4], Auroral Light | Charge Deposition, Scintillation, Dosage | Charging Auroral Light | Discoloration Scintillation | Surface fogging, Contamination, | ——— Surface Damage ——— | |
| Orbit/Pointing Accuracy | Atmospheric Heating | | | | Aerodynamic Drag | | |

* Modified by Shuttle
1 Includes Cosmic Rays
2 Charging always results of net current balance
3 $\alpha$ absorplivity; $\epsilon$ emissivity
4 Influences Contamination rate

FIGURE 1

## ELECTRO-MAGNETIC FIELDS AND WAVES

| EFFECTS / EFFECTS ON | DC<br>(INF) | $10^5$<br>$10^5$ | $10^{10}$<br>1<br>MICROWAVES | IR VISIBLE | $10^{15}$ Hertz<br>$10^{-5}$ cm<br>UV |
|---|---|---|---|---|---|
| Bio-Medical | No Concern — | EMI → | Damage to Tissue — | Visual — | Sunburn — |
| Large Structures | Induced Currents, VXB, torques, Drag | — | Multipacting — | Thermal Stress — | Material Damage, Atmospheric Perturbations |
| Electrical Systems | — EMI and Noise Sources Depending on Communications — | | | | |
| Optical Systems | — No concern — | | | Thermal Stress — | Background, — Material Damage |
| Orbit/ Pointing Systems | Location, Joule Heating, VXB torques — | | No Concern — | | Atmospheric — Perturbations |

FIGURE 2

# IMPS PAYLOAD A

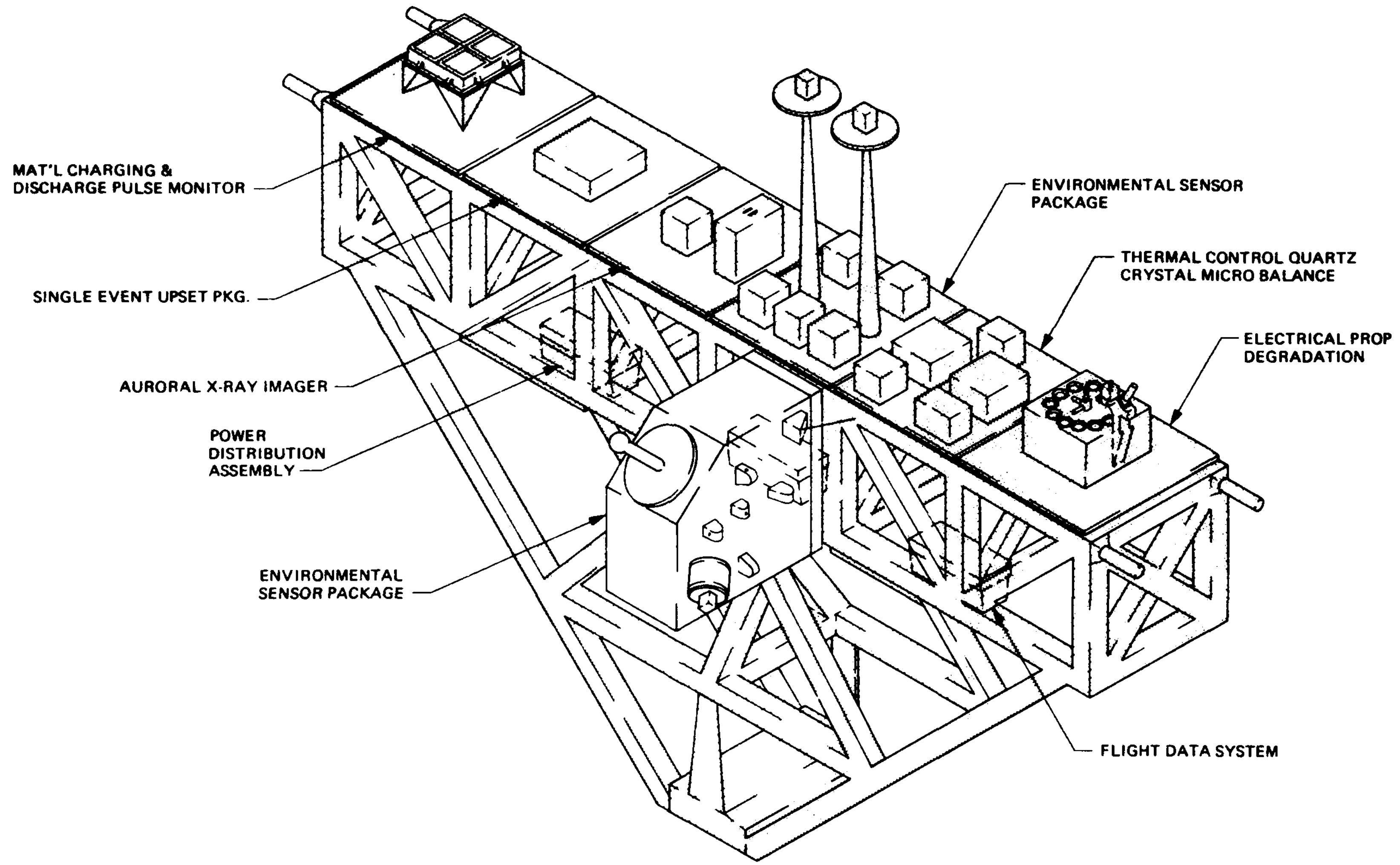


FIGURE 3

# IMPS PAYLOAD, MOD B

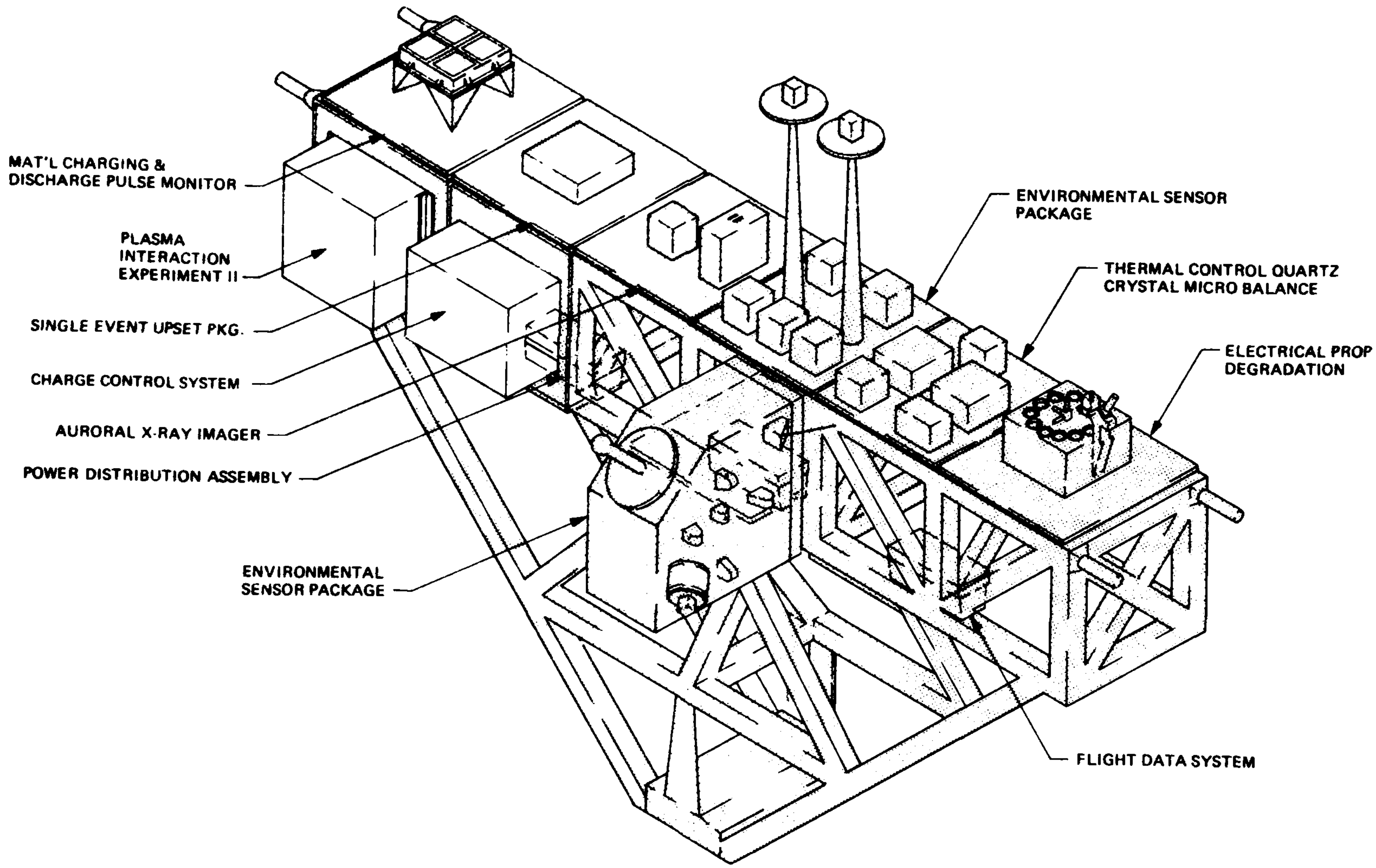


FIGURE 4

# IMPS PAYLOAD, MOD C

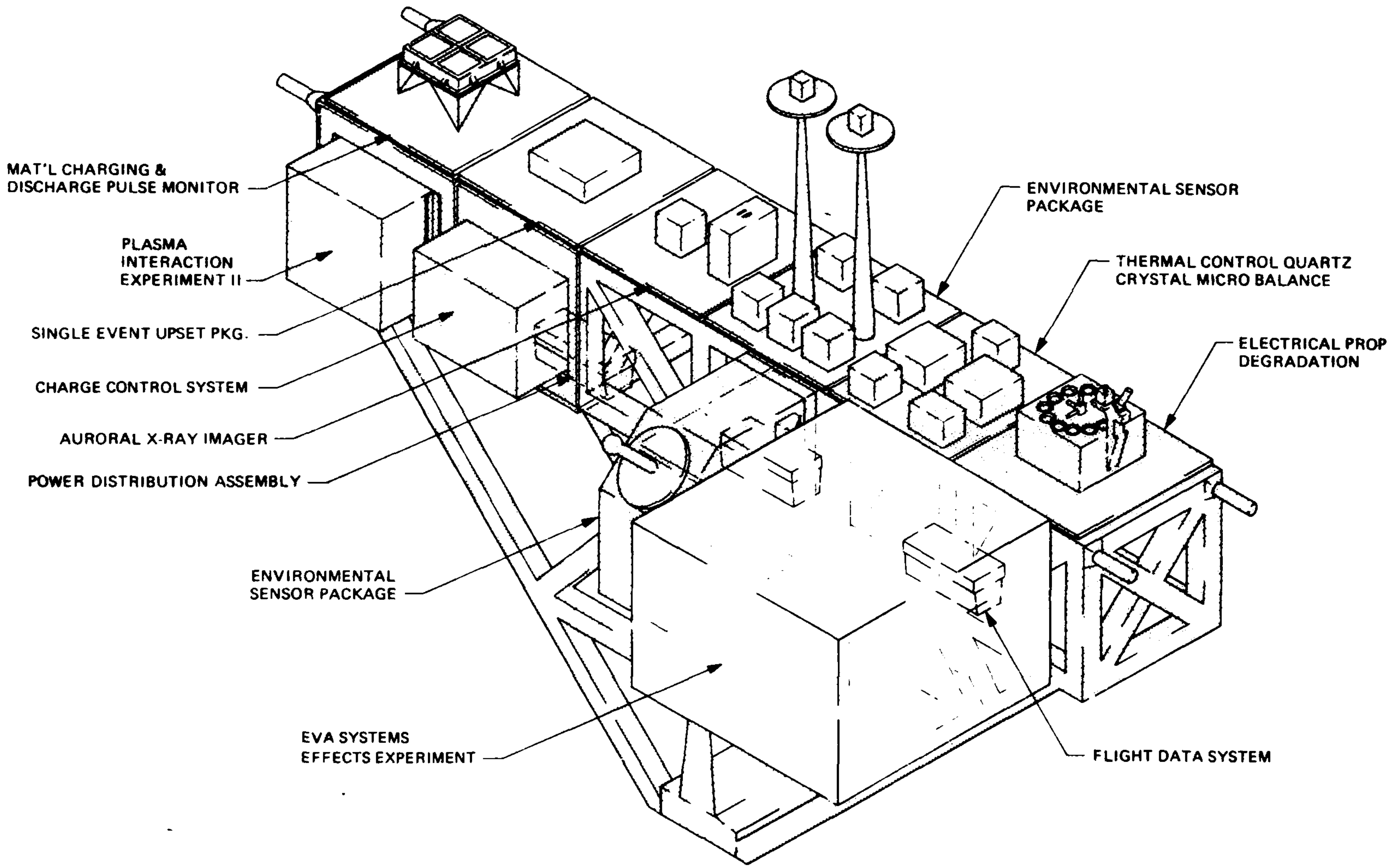


FIGURE 5

# AFGL ENVIRONMENTAL SENSOR PACKAGE

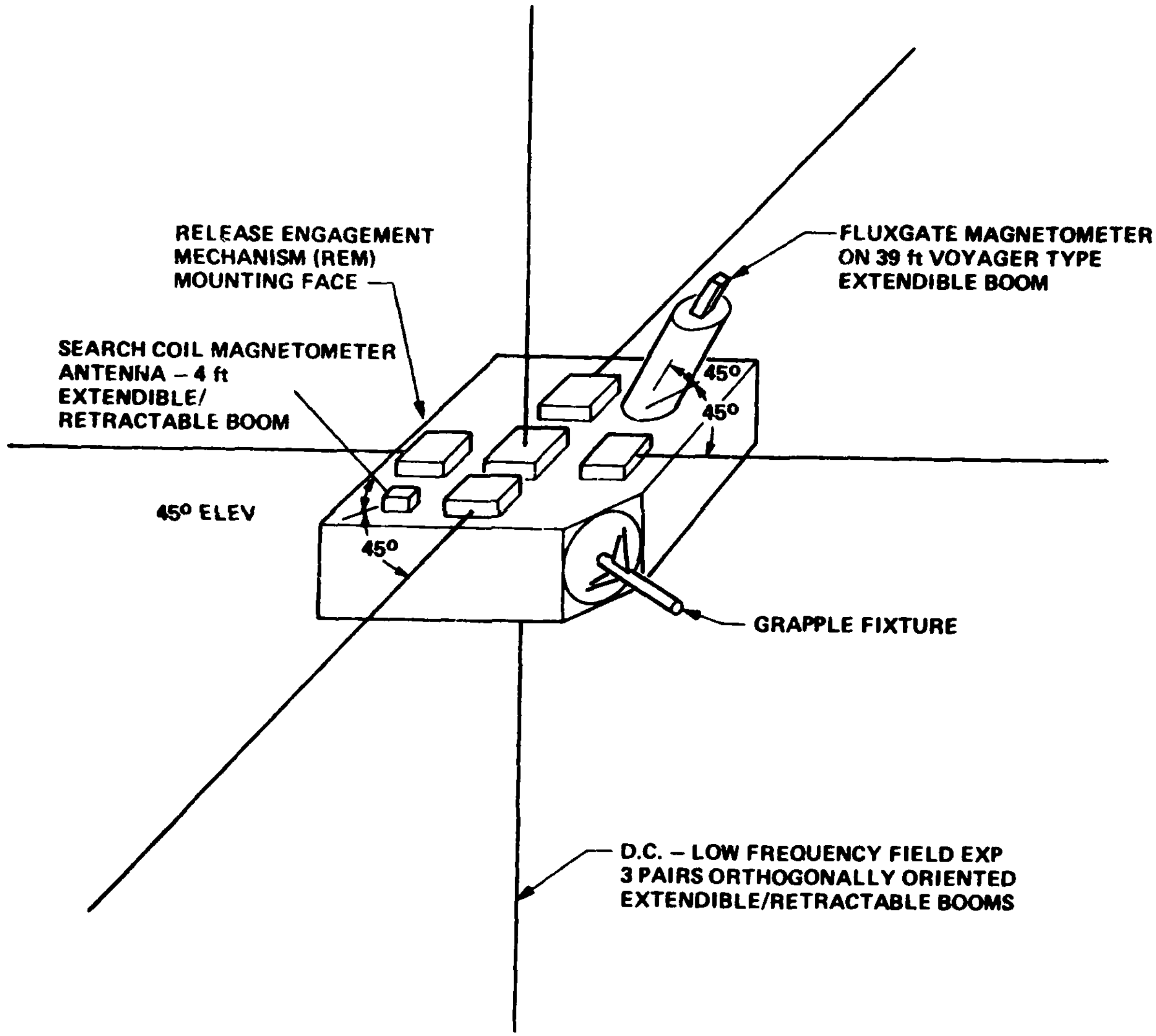


FIGURE 6

Imps

# IMPS GROUND TRACK

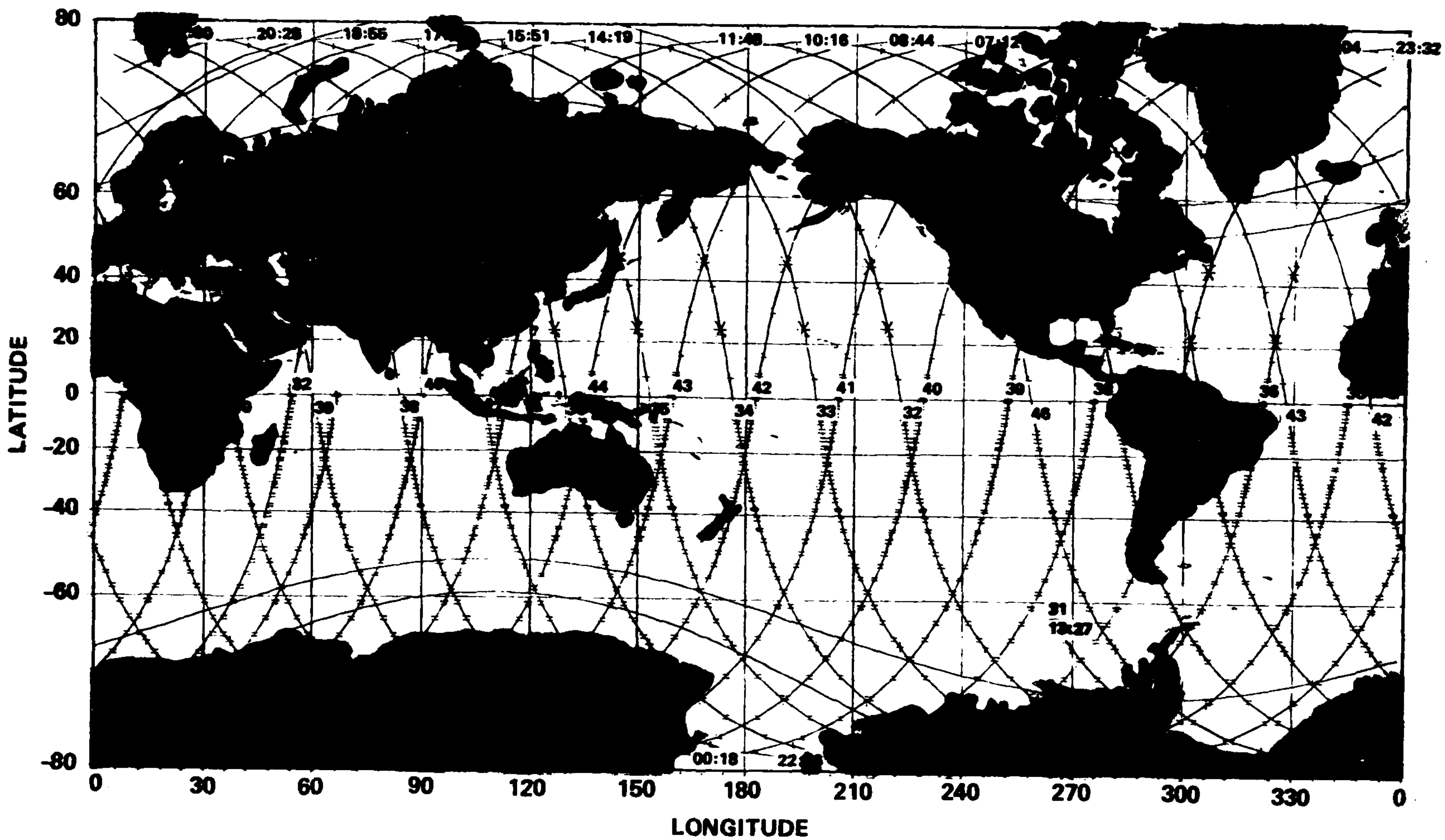


FIGURE 7

# IMPS MISSION PECULIAR EQUIPMENT STRUCTURE

## PAYLOAD CG ENVELOPE FOR MAXIMUM LOAD CAPACITY

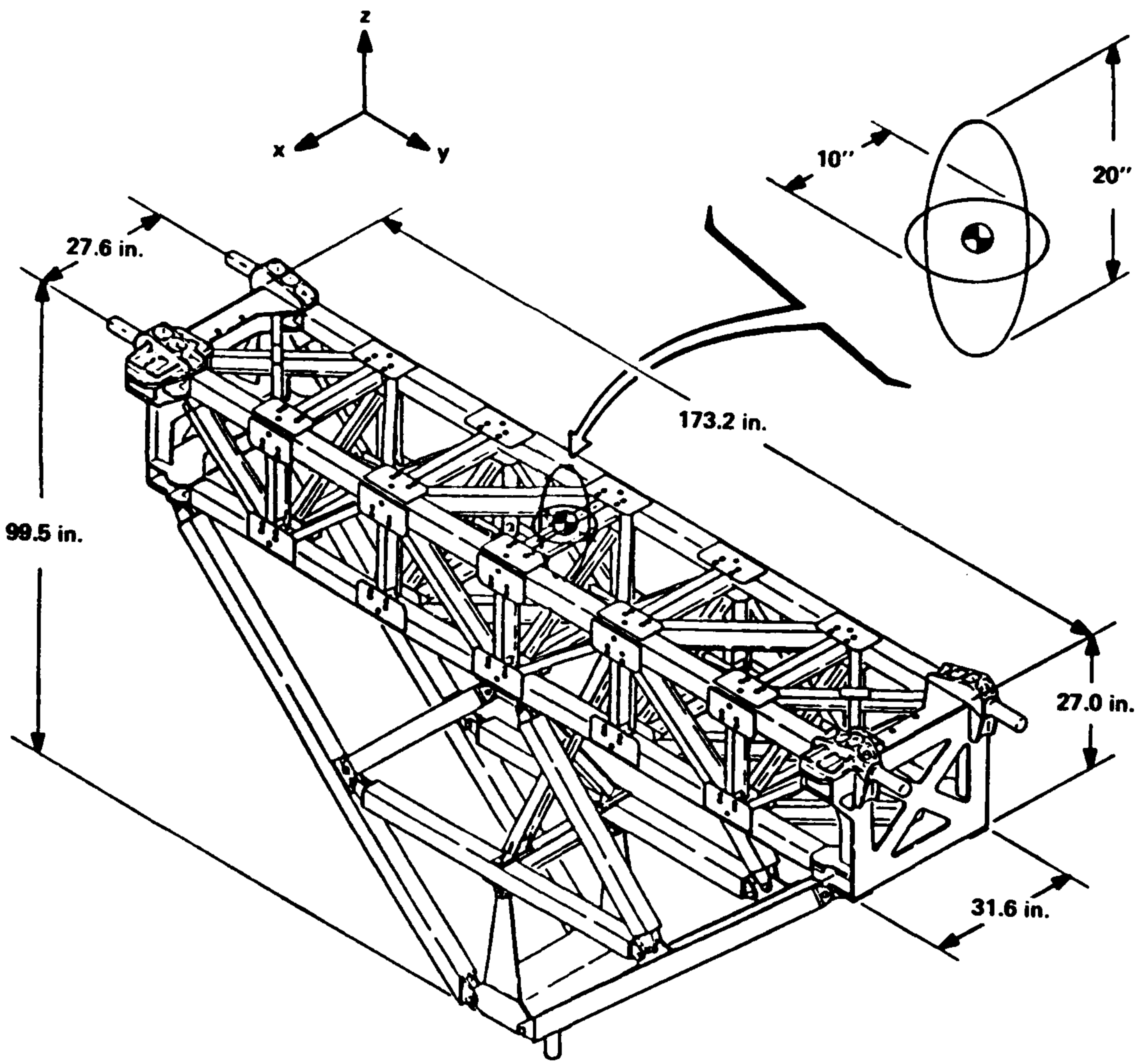


FIGURE 8

# IMPS INSTRUMENTATION
## (PRELIMINARY PAYLOAD)

| PAYLOAD | INSTRUMENT | EXPERIMENTER |
|---|---|---|
| A | ELECTRICAL PROPERTIES DEGRADATION | H. GARRETT (JPL) |
| A | MATERIALS CHARGING AND DISCHARGING PULSE MONITOR | P. MIZERA (AEROSPACE) |
| A | ELECTROMAGNETIC INTERFERENCE MEASUREMENTS IN SHUTTLE BAY | D. FORTNA (GSFC) |
| A | SINGLE EVENT UPSET PACKAGE | W. PRICE (JPL) |
| A | TQCM | D. HALL (AEROSPACE) |
| A | AURORAL X-RAY IMAGER | D. McKENZIE (AEROSPACE) |
| A | ENVIRONMENTAL SENSOR PACKAGE | AFGL |
| B | CHARGE CONTROL SYSTEM (PROJ 2823) | B. SHUMAN |
| B | PLASMA INTERACTION EXPERIMENT | N. J. STEVENS (LEWIS) |
| C | EVA SYSTEMS EFFECTS EXPERIMENT | A. KONRADI (JOHNSON) |

TABLE 1

# IMPS INTEGRATED TIMELINE
# TYPICAL SINGLE ORBIT

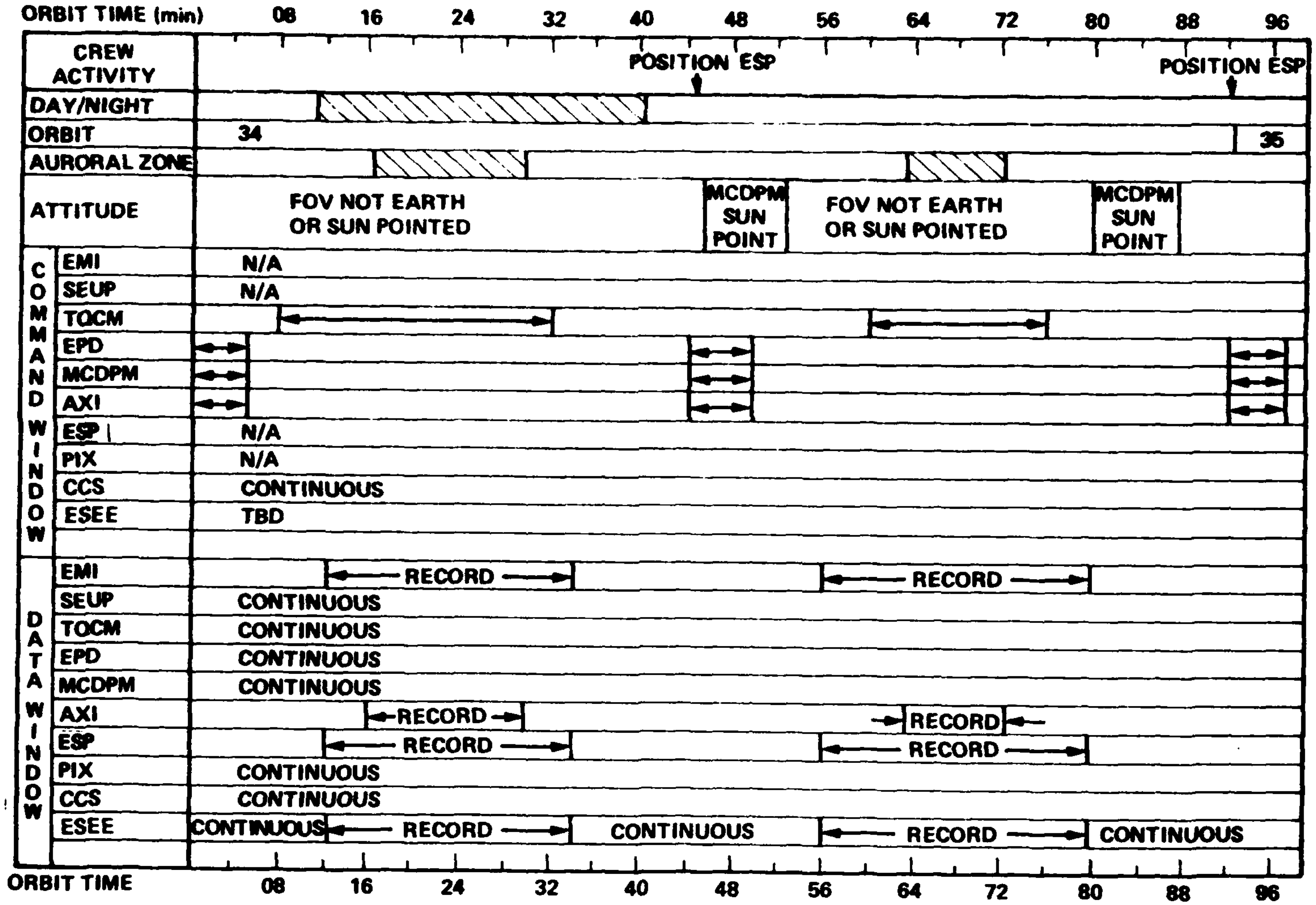


TABLE 2

# PROPELLANT USE ESTIMATION

USAGE - (1814 kg AVAILABLE)

LIMIT CYCLE USE ($\pm 0.1^\circ$ dB) = 2 kg/hr = 336 kg/MISSION

MANEUVERS (AT $0.25^\circ$/sec)

| | |
|---|---|
| ROLL | 1.8 kg |
| PITCH | 2.8 kg |
| YAW | 3.3 kg |
| THREE-AXIS | 7.9 kg |

| MCDPM EXAMPLE | ROLL ONLY | 3-AXIS |
|---|---|---|
| SUN POINT/RETURN | 3.6 kg | 15.8 kg |
| ORBIT | 7.2 kg | 31.6 kg |
| DAY | 79.2 kg | 347.6 kg |

TABLE 3

# ACCURACIES

POSITION KNOWLEDGE (meters)

| | ALTITUDE | DOWNRANGE | CROSS-RANGE | SOURCE |
|---|---|---|---|---|
| REQUIRED | 100 | 10 K | 1 K | ESP |
| CAPABILITY | 90 | 430 | 460 | TDRSS |

VELOCITY KNOWLEDGE (m/s)

| | ALTITUDE | DOWNRANGE | CROSS-RANGE | SOURCE |
|---|---|---|---|---|
| REQUIRED (0.1) | TBD | TBD | TBD | ESP |
| CAPABILITY | 0.5 | 0.11 | 0.15 | TDRSS |

POINTING

| | ACCURACY | STABILITY | RATE (°/S) | SOURCE |
|---|---|---|---|---|
| REQUIRED - KNOWLEDGE | 0.5° | 0.3° | 0.005 | ESP |
| - CONTROL | TBD | TBD | TBD | |
| CAPABILITY - KNOWLEDGE | TBD | TBD | TBD | |
| - CONTROL* | ±0.5° | ±0.1° | 0.01 | ORBITER |

*ALIGNMENT ERROR ~2°

TABLE 4

# IMPS DATA HANDLING

| EXPERIMENT | | MODE (FORMAT) | DIGITAL (bps) | DISCRETE (STATUS) | | ANALOG | | | TOTAL RATE (MAX) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NO | RATE | NO | SAMPLE RATE | DATA RATE | R/T | RECORD |
| EMI | | NORMAL (3 SET) | 2400 | -- | -- | 3 | 1/S | 24 | | |
| | | LOW DWELL (3 SET) | 4800 | -- | -- | 3 | 1/S | 24 | | 4824 |
| SEUP | | NORMAL | 100 | -- | -- | -- | -- | -- | 100 | -- |
| PIX | | NORMAL | 64 | -- | -- | -- | -- | -- | 64 | -- |
| TQCM | | NORMAL | 96 | -- | -- | 18 | 1/S | 144 | 240 | -- |
| EPD | | NORMAL | 240 | -- | -- | -- | -- | -- | 240 | -- |
| MCDPM | | NORMAL | 256 | 12 | 1/min | ? | 1/min | | 256 | -- |
| ESP | SCMAG | NORMAL | 320 | | | | | | | |
| | FGMAG | NORMAL | 840 | -- | -- | -- | -- | -- | | |
| | SPEC | NORMAL | 1920 | | | | | | | |
| | THPLAS | NORMAL | 1024 | | | | | | | |
| | LFEF | NORMAL | 1600 | 16 | | | | | -- | 5704 |
| AXI | | STANDBY | -- | 10 | 1/S | ? | 1/S | | | |
| | | OPERATE | 20 K | 10 | 1/S | ? | 1/S | | -- | 20,000 |
| CCS | | NORMAL | 5000 | | | 16 | 1/16S | 8 | 5008 | -- |
| ESEE | | NORMAL | 100 | | | | | | | |
| | | OPERATE | 1100 | | | | | | 100 | 1000 |
| TOTAL | | | | | | | | | 6908 | 31,528 |

TABLE 5

# IMPS POWER REQUIREMENTS - MOD C PAYLOAD

| | | AVG | PEAK | DUTY CYCLE | ENERGY w-hr/hr |
|---|---|---|---|---|---|
| ESP | | 19 | 20 | CONT | 19 |
| EMI | | 50 | 60 | CONT | 50 |
| SEUP | | 50 | 50 | CONT | 50 |
| TQCM | | 10 | 20 | CONT | 10 |
| EPD | | 20 | 20 | CONT | 20 |
| MCDPM | | 14 | 14 | CONT | 14 |
| AXI | OPERATE | 7 | 7 | 25% | |
| | STANDBY | (1) | (1) | CONT | 3 |
| CCS | OPERATE | 37 | 67 | ? | |
| | STANDBY | (3) | (3) | CONT | 37 |
| PIX | | 15 | 140 | CONT | 15 |
| ESEE | | 50 | 50 | 33% | 17 |
| DATA SYSTEM | | 26 | 26 | CONT | 26 |
| POWER DIST | | 5 | 5 | CONT | 5 |
| TOTAL | | 303 | 497 | | 266 |

TABLE 6

# IMPS MASS SUMMARY
# MOD C PAYLOAD

| INSTRUMENT | | ASSEMBLY | MASS (kg) | TOTAL |
|---|---|---|---|---|
| EMI | | MAG SWITCHING UNIT | 0.5 | |
| | | PROGRAMMER/ SWITCH UNIT | 22 | |
| | | RECEIVER | 27 | |
| | | MAG CONTROL UNIT (3) | 1 | |
| | | PROBES (3 SETS) | 20 | 70 |
| SEUP | | SENSOR | 23 | 23 |
| TQCM | | SENSOR A | 1.7 | |
| | | SENSOR B | 1.7 | |
| | | CONTROLLER | 3.9 | |
| | | ELECTROMETER | 3.9 | |
| | | CONTAMINATION SOURCE | 4.5 | 16 |
| EPD | | INSTRUMENT | 14.5 | 15 |
| MCDPM | | INSTRUMENT | 4 | 4 |
| ESP | SCMAG | ANTENNA | 2 | |
| | | ELECTRONICS | 2 | |
| | | BOOM | 3 | |
| | FGMAG | SENSOR | 0.5 | |
| | | ELECTRONICS | 1.5 | |
| | | BOOM | 4.0 | |
| | SPEC | INSTRUMENT | 3.5 | |
| | THPLAS | PROBE | 0.5 | |
| | | RPA | 0.5 | |
| | | ELECTRONICS | 3 | |
| | | BOOM | 1 | |
| | LFEF | ELECTRONICS | 2 | |
| | | ANTENNA (6) | 8 | 32 |
| AXI | | CAMERA | 16 | |
| | | ELECTRONICS | 4 | 20 |

TABLE 7a

## IMPS MASS SUMMARY MOD C PAYLOAD
## (contd)

| INSTRUMENT | ASSEMBLY | MASS (kg) | TOTAL |
|---|---|---|---|
| ESEE | ASSEMBLY | 338 | 338 |
| PIX | STRUCTURE | 12.7 | |
| | PROBES | 2.3 | |
| | THERMAL BLANKET | 0.7 | |
| | ELECTRONICS 1 | 4.5 | |
| | ELECTRONICS 2 | 3.6 | |
| | ELECTRONICS 3 | 11.6 | |
| | SOLAR PANEL | 9.5 | 45 |
| CCS | ASSEMBLY | 13 | 13 |
| DATA SYSTEM | ASSEMBLY | 17 | 17 |
| POWER DISTRIBUTION | ASSEMBLY | 6 | 6 |
| PLATFORM | ASSEMBLY | 40 | 40 |
| STRUCTURE | ASSEMBLY | 540 | 540 |
| | | TOTAL | 1176 |

Table 7b

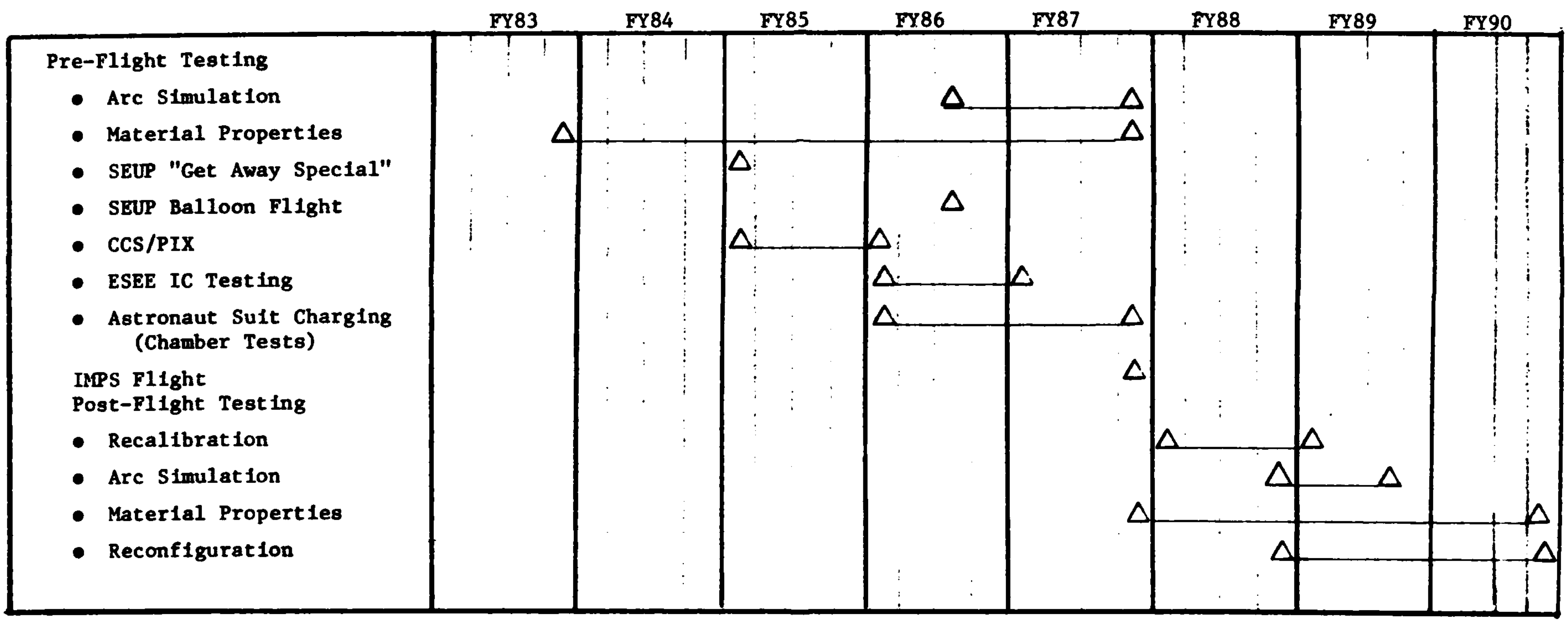


TABLE 8. IMPS Ground Test Support Plan

TABLE 8

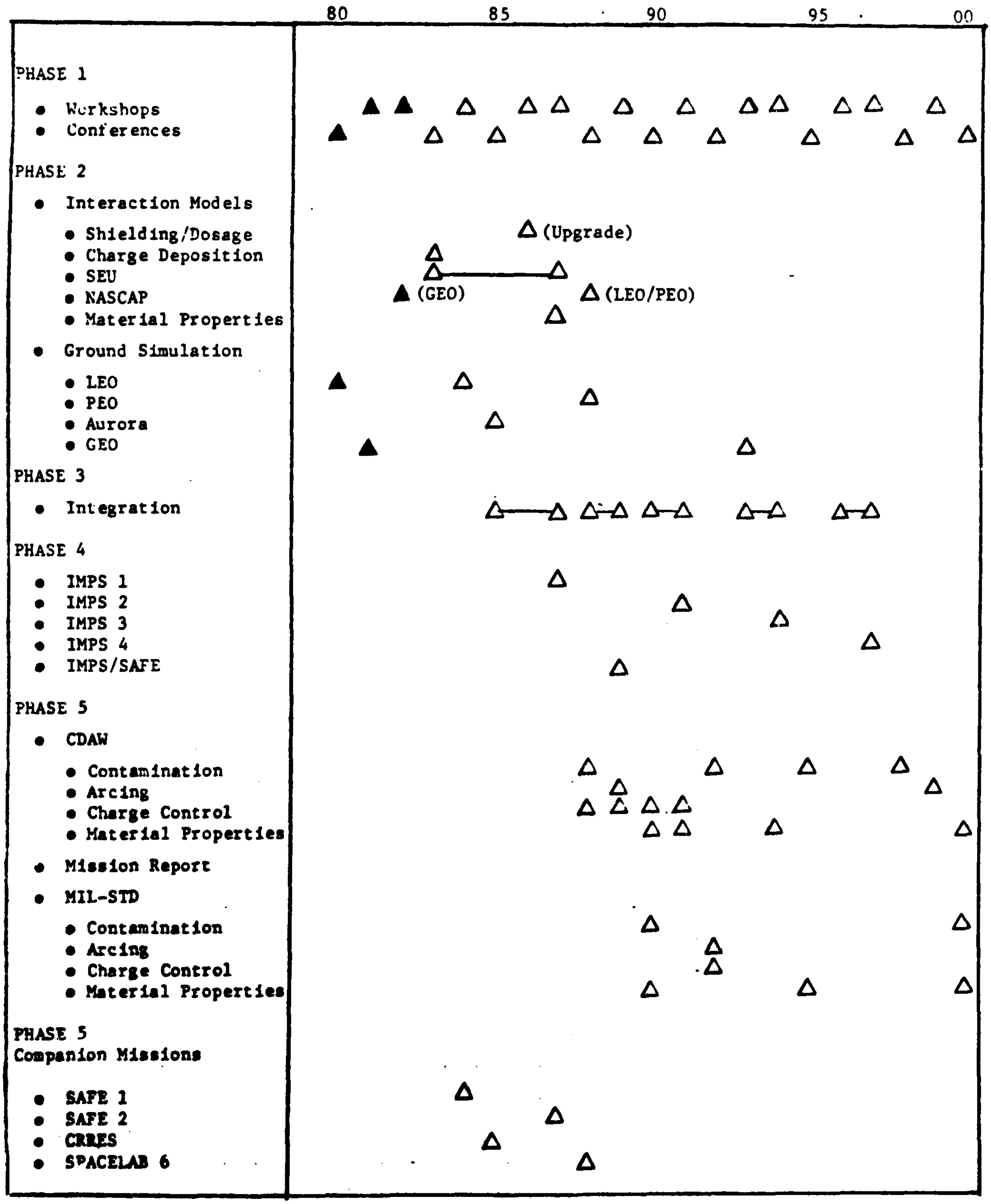


**TABLE 9. Master Timeline for IMPS 1980-2000**

- SPACE PLASMAS
- IONOSPHERE/ATMOSPHERE
- RADIATION EFFECTS
- CHARGING/PLASMA INTERACTIONS
- CONTAMINATION
- MATERIAL PROPERTIES
- ASTRONAUT SAFETY

TABLE 10. IMPS PANELS

TABLE 11

| Interaction | Experiment | Ground-Simulation | Analysis |
|---|---|---|---|
| A. Radiation Effects | 1. High time resolution mass spectrometer on IMPS<br>2. Samples of high density micro-circuits on IMPS LDEF<br>3. Charge deposition measurements | 1. Develop "natural" radiation simulation<br>2. Develop techniques for simulating long duration exposure | 1. Charge deposition modeling<br>2. SEU prediction<br>3. Astronaut EVA dosage models |
| B. Spacecraft Charging | 1. Charged beams experiment<br>2. Sheath and wake measurements<br>3. Photoelectron, backscatter, and secondary emission properties<br>4. Arc discharge stimulation and monitoring<br>5. Surface potential monitoring<br>6. Systems response study | 1. Develop shuttle, geosynchronous, and polar simulation environments<br>2. Develop arc simulation techniques<br>3. Sheath and wake simulation | 1. Develop NASCAP and similar models<br>2. Develop low altitude plasma sheath models<br>3. Develop material response models |
| C. Large, High Voltage Structures | 1. Exposed, high potential surfaces of varying size, construction, and potential<br>2. Sheath measurements<br>3. Test shielding methods | 1. Chamber testing<br>2. Test shielding methods | 1. Compare NASCAP and similar models at geosynchronous<br>2. Test low altitude plasma sheath models |
| D. Contamination | 1. Surface contamination monitors<br>2. Measure artificially induced contamination | 1. Simulate launch environment<br>2. Simulate space contamination/degradation<br>3. Develop thruster simulations | 1. Computer simulation of deposition |
| E. Environmental Effects | 1. Launch exhausts measurements<br>2. Wake-induced wave measurements<br>3. Meteoroid/debris measurements<br>4. Chemical release studies<br>5. Particle Depletion Measurements<br>6. Microwave heating/turbulence measurements<br>7. Measure ambient environment | 1. Rocket Plume measurements<br>2. Radar cross-section studies<br>3. Chemical reaction studies | 1. Test atmospheric reactions models<br>2. Compare chemical releases with theory<br>3. Simulate ionospheric changes<br>4. Confirm magnetospheric models |